Recreational Demand for Shellfish Harvesting Under Environmental Closures

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ABSTRACT

The Puget Sound estuary provides one of the most valuable shellfish habitats in the Pacific Northwest, USA. Shellfish are important economically, ecologically, and socially to the Puget Sound basin. The State of Washington manages the safety of shellfish harvest areas by assessing water quality on an ongoing basis and instituting advisories and closures based on water quality thresholds. Managers currently have little information to understand the effect of these closures on harvesting effort or economic values. In order to address this important need, we recently conducted a contingent behavior survey of recreational shellfish harvesters that use Puget Sound beaches. The survey elicited the number of annual trips respondents would expect to take under alternative closure scenarios, including a baseline of no closure. We estimate the demand for recreational trips using a count model system, quantifying the economic value lost to harvesters when beaches are closed due to pollution or biotoxins.

Key words: Biotoxin, contingent behavior, pollution, Puget Sound, recreational demand, shellfish harvesting.
JEL Codes: Q53, Q26.

INTRODUCTION

Consumption advisories and harvest closures are increasingly required to protect human health from pollution and toxins produced by harmful algal blooms (HABs), constraining recreational and commercial harvest opportunities. On a global level, the frequency of HAB events has been increasing (Glibert et al. 2005; Van Dolah 2000). A similar pattern is seen with bacterial and chemical pollution, largely due to changes in land use and the extent of impervious surfaces (Fleming et al. 2006; Glasoe and Christy 2004; Mallin et al. 2000; Sandifer et al. 2004).

Within the Pacific Northwest, an increasing trend of HAB events has also been observed, mirroring the global trend. Toxins produced by HABs within Puget Sound have increased over the past four decades in both incidence and geographical scope (Trainer et al. 2003). Nonpoint source pollution, such as stormwater runoff, sewage systems, and farm animal waste, has been cited as the leading cause of new pollution closures (Glasoe and Christy 2004). These water quality issues are partially a function of past changes in nearshore habitats that have reduced the

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[†] Deceased. Mark Plummer passed away during the writing of this article. He was a highly respected colleague and a caring mentor. He will be greatly missed.

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natural capacity to moderate runoff and absorb contaminants; forested lands have been converted to agricultural, residential, and urban lands (Glasoe and Christy 2004).

In this article, we focus on recreational clam and oyster harvesting in Puget Sound, Washington. The estuary provides perhaps the most valuable shellfish habitats in the Pacific Northwest, though harvesting opportunities are regularly constrained by health-related closures. We explore the effect of these closures on recreational use values and the extent to which harvest effort shifts to substitute trip types: harvest trips to nearby beaches that remain open and non-harvest beach trips.

The recreational harvest of shellfish in Puget Sound is managed for both biological conservation of the species and the protection of human health. Appropriate harvest levels are set in order to maintain sufficient biomass, using season length and daily harvest limits as instruments to achieve the targeted harvest. In addition, shellfish growing areas are classified based on water quality, including current and potential pollution sources. The result of this classification is a determination of whether or not shellfish in the area can be harvested for human consumption. Shellfish are also routinely tested for biotoxins known to be present, such as paralytic shellfish toxins, domoic acid, and diarrhetic shellfish toxins. These biotoxins, produced by microscopic algae, concentrate in filter feeders and are not destroyed by cooking. When toxins exceed established thresholds and shellfish are deemed unsafe for human consumption, the area is closed to harvest. Harvest closures may also be issued in response to high pollution levels (bacteria or other), as well as viruses (norovirus). Although the temporal and areal extents of closures vary widely, pollution closures tend to be in place longer than biotoxin closures, at times spanning many years (Dethier 2006). Closures are posted online, in other media, and often at public beaches.

The Puget Sound Partnership, a Washington State agency established to facilitate the conservation and restoration of Puget Sound, has set a priority to reduce shellfish growing area closures to increase recreational and commercial harvest opportunities. As of April 2013, 35,801 acres of shellfish beds were closed due to pollution sources—about 19% of the total shellfish beds. The Partnership has set a goal of 10,800 additional harvestable acres by 2020 over the 2007 baseline of 138,684 acres (Puget Sound Partnership 2011, 2012).

There is little information that managers can use to assess the value of such changes in harvest opportunities. Our review of the literature, as well as a recent review prepared for the Pacific Shellfish Institute (Northern Economics, Inc. 2009), finds relatively few examples of recreational shellfish valuation studies. There have, however, been a significant number of articles estimating the recreational demand for trips within a related set of contexts, including measuring the effects of closures for finfish and related consumption advisories on recreational demand (e.g., Phaneuf, Kling, and Herriges 2000; Jakus et al. 1997), and the recreational demand for (non-harvest) beach trips (e.g., Whitehead et al. 2008; Parsons et al. 2013; Bell and Leeworthy 1990; Awondo, Egan, and Dwyer 2011; Parsons et al. 2009; Penn et al. 2016). Focusing on shellfish harvesting, Damery and Allen (2004) used an open-ended contingent valuation survey of permit holders in Cape Cod, Massachusetts, to estimate the maximum willingness to pay (WTP) to purchase a permit as well as the minimum willingness to accept to give it up. The demand for harvesting licenses in Massachusetts was also estimated using license purchase data (English 2010). Though these two studies estimate the annual value of harvesting, they are not well suited to address harvest closures. We were able to locate just one study that links recreational harvest closures to economic value; Beaumais and Appéré (2010) used an on-site survey in France to ask shellfish harvesters the maximum number of kilometers they were willing to travel in order to continue to harvest shellfish on a substitute beach that was not affected by two hypothetical sanitary quality deteriorations. The economic impacts of harvest closures in Washington or Oregon have been more studied, with two studies estimating the economic impact of razor clam harvesting on the ocean beaches (Dyson and Huppert 2010; Hoagland et al. 2002). In the Pacific Northwest, there have been no valuation studies of recreational clam or oyster harvesting;[1] this article represents the first economic valuation of recreational shellfish harvesting in the region.

The values we find could be used, for example, to assess the lost consumer surplus from harvesting closures put in place in response to things like failing septic systems or potential oil spills. In order to provide this information, we recently conducted a survey of recreational shellfish harvesters in Puget Sound in order to estimate the effect of environmental closures on harvester behavior. The survey elicited the annual number of trips respondents would expect to take under alternative closure scenarios, including a baseline of no closure, using scenarios generated by an experimental design. The use of an experimental design is a novel approach to eliciting trip counts on a contingent behavior (CB) survey. We estimate the demand for recreational trips using an incomplete demand system count model, using the model to quantify the economic value lost to shellfish harvesters when beaches are closed due to pollution or biotoxins. Our model allows us to explicitly quantify substitution to other (open) beaches for harvest, as well as substitution to non-harvest trips to the same (closed) beach. General findings suggest that although some harvest would continue to occur during a closure and there would be significant substitution to nearby beaches that remain open, the overall net effect of a harvest closure across all trip types would be a sizeable reduction in both effort and value.

METHODS

The basic approach we use to estimate the demand for recreational shellfish harvesting trips is an incomplete demand system (LaFrance 1990; von Haefen 2002). We model the demand for three recreational goods in Puget Sound: harvest trips to each respondent's most-used beach (*harvest*), non-harvest trips to the same beach (*non-harvest*), and harvest trips to a nearby substitute beach (*alternate*). In particular, we use a CB framework to elicit trip demand under closure scenarios of varying type and extent, including a baseline of no closure.[2] Of course, these methods are an extension of the original travel cost methodology (Burt and Brewer 1971) since recreational harvesters need to travel to a site in order to enjoy its services.

MODEL

We follow the common approach of using a semi-logarithmic functional form to specify the incomplete demand system (Bartczak, Englin, and Pang 2011; Englin, Holmes, and Niell 2006). If we let demand for trip type i be denoted by x_i, the model is:

$$x_i = \alpha_i(z)\, exp(\Sigma_k \beta_{ik} P_k + \gamma_i y), \tag{1}$$

1. There is one questionable exception. A report by TCW Economics (2008) takes values from the Boyle et al. (1998) database of sport fishing values, under the assumption that entries with unspecified species correspond to shellfish, yielding an estimate of $43 per day for Washington.

2. While Beaumais and Appéré (2010) also elicit recreational shellfish harvest trips to a substitute site conditional on declining water quality, our approach differs in a few ways. First, our methodology more fully captures substitution as we model harvest trips, non-harvest trips, and harvest trips to a substitute site. Second, the distance to the substitute beach was part of our experimental design and was provided to respondents in the CB questions, rather than asking respondents with an open-ended format.

where $\alpha_i(z)$ represents the effect of a set of non-income demand shifters (z), β_{ik} is the effect of the cost of trip type k (P_k), and γ_i is the effect of income (y). Several parameter restrictions are necessary to ensure integrability (von Haefen 2002): the income parameter is fixed across trip types ($\gamma_i = \gamma_k$), cross-price effects are zero ($\beta_{ik} = 0, \forall i \neq k$),[3] own-price coefficients are negative ($\beta_{ii} < 0$), and the effect of the demand shifters is positive ($\alpha_i(z) > 0$).

Using an exponential functional form for $\alpha_i(z)$ ensures this last condition is met. We include closure types as potential non-income demand shifters in our application, allowing the effect of closure types to vary across trip types. In addition, respondents who use a private beach (*Priv*) are allowed to have differential demand for trips:

$$\alpha_i(z) = exp(\theta_i + \rho Priv + \Sigma_n \delta_{ni} Closed_n), \tag{2}$$

where the effect of closure type n ($Closed_n$) is given by δ_{ni}.

Given the restrictions provided above, the demand for trip type i becomes:

$$x_i = exp(\theta_i + \rho Priv + \Sigma_n \delta_{ni} Closed_n + \beta_i P_i + \gamma y). \tag{3}$$

Heterogeneous baseline preferences for different trip types may be handled in the model by allowing the set of θ_i to be randomly distributed across respondents during estimation. In practice, this is accomplished by making an assumption regarding the distribution, typically normal, and estimating both a mean and standard deviation (Train 2009).

DATA

The data we use to model recreational shellfish harvester behavior are taken from a survey of licensed harvesters. In 2013, a mail survey was administered to a random sample of Washington state residents who harvested clams or oysters recreationally in Puget Sound.[4] To accomplish this, we first used a telephone survey to identify individuals who had harvested clams or oysters within the last 12 months.[5] The full survey instrument was then sent to all individuals who confirmed harvesting, as well as individuals who were unable to be reached by the telephone survey. The mail survey was administered following the general procedures outlined in Dillman (2000), including a prenotice letter, the first full mailing of the questionnaire, a postcard reminder, and two final mailings of the questionnaire.

The questionnaire was developed and tested through a series of focus groups and one-on-one interviews with recreational shellfish harvesters in the region. The final survey was administered to a pretest sample (n = 400) prior to final administration. As no issues were discovered in the pretest, we include these responses in our analysis. Including the pretest sample, the survey was sent to 4,102 individuals. In order to calculate the response rate, we first estimated the percent-

3. Note, however, that the compensated cross-price effects are equal to $\gamma x_i x_k$ and will be non-zero if respondents take trips of more than one type in our system and γ is non-zero.

4. We define harvesters as recreational, rather than subsistence, based on drawing our sample from the recreational license database.

5. License data are not sufficient to identify Puget Sound shellfish harvesters. For example, shellfish licenses are also purchased to harvest razor clams on ocean beaches (not the subject of this study) and combination licenses allow many different uses, including fishing in freshwater or saltwater. We identify Puget Sound shellfish harvesters by their stated activity in the last 12 months. Overall, we estimate that 15.4% of those who hold a shellfish or combination license harvested clams or oysters in Puget Sound. Note, however, that our sampling approach does not result in a truncation of CB trip counts at one, as would be the case with on-site sampling approaches. The reliance on current harvesters may omit potential future harvesters for analyses of policies that increase the general rate of participation in recreational shellfish harvesting (e.g., large-scale openings of areas currently closed for pollution).

age of license holders that harvest clams or oysters in Puget Sound: 15.4%. Among this population, the survey achieved an estimated response rate of 50.2%.

The survey collected data on general shellfish harvesting behavior over the last 12 months, including the location of the beach used most often by each respondent. Further detail was obtained on the most recent harvest trip, as some of these expenditures are necessary in the travel cost calculations. Next, respondents were provided a set of CB questions—the basis for our present analysis—before closing the survey with demographic questions.

Clam and oyster harvesting seems to be an important recreational activity; respondents reported an average of 3.7 and 2.4 days harvesting clams and oysters per year, respectively, from Puget Sound beaches (table 1). Not surprisingly, these harvesting trips were a source of food for many respondents. A majority of respondents consumed four or more meals per year containing their harvest, with 18% consuming more than 10. Most harvesters (65%) relied on a single beach for harvest, exclusively, and reported using a public beach more often than a private beach (73%). Respondents averaged 53 years old, with annual household incomes of $80,242, and most respondents were male (66%). The average distance traveled to reach a harvesting beach was approximately 34 miles, and the round-trip travel cost of a harvesting day was estimated to be $29.86 (table 1). For more detail on the survey, the characteristics of respondents, as well as summaries of the responses, see Anderson and Plummer (2016).

The CB questions were designed to gather data on the demand for trips for each respondent, conditional on the status of harvest closures at their most used beach. We first asked respondents to provide a baseline level of harvesting and non-harvesting trips to the beach they use most often. In order to establish a consistently defined baseline, respondents were asked to provide this level of effort conditional on a scenario of no beach closures for biotoxin or pollution.[6] Next, we presented a set of two annual closure scenarios[7] (figure 1) that varied by type (pollution or biotoxin), species closed to harvest (all clams and oysters or butter clams only), and additional distance to a nearby beach that is fully open (5, 10, 20, or 30 miles).[8] For each closure scenario, respondents were asked to provide harvest trips to their most used beach, harvest trips to the alternate (open) beach, and non-harvest trips to their most used beach. The result was a pseudo panel consisting of 10 trips from each respondent: two CB scenarios each with three trip types plus a set of four baseline trip levels.[9] The levels for the distance attribute were selected with the help of recreational shellfish harvesters through the survey pre-testing process. Levels for the type of closure attribute and species closed to harvest attribute were chosen to correspond to current and past closures in Puget Sound; pollution closures that only affect butter clams have

6. Note that a baseline of no closures may not perfectly match the expected level of closures that would occur in the upcoming year for some harvesters. Standardization was chosen in order to avoid a baseline characterized by respondent-specific heterogeneity and significant uncertainty, as closures are not known in advance for the upcoming year. Nonetheless, focus group participants and one-on-one interviewees confirmed that the scenarios we presented were considered realistic: substantial spatiotemporal heterogeneity in closures has made harvesters familiar with beaches that remain open all year as well as beaches that remain closed all year.

7. Of course, this limits the direct application of this model to longer-term closures. Pollution closures are commonly instituted for longer periods of time and, as such, represent the most straightforward application of the annual CB scenarios presented here. Ongoing research is being conducted to model the effect of closures of a shorter term, better suited for the most common lengths of biotoxin closures. Importantly, focus groups and cognitive interviews with harvesters indicated that annual closures were very believable, as many beaches in the Sound have faced multi-year pollution closures, and some beaches have faced very persistent biotoxin closures.

8. This is part of a larger study that will also look at closures that vary in length as well as time of year. Partial year closures will be the subject of future research.

9. The survey allowed baseline *alternate* trips to vary based on the distance presented in the CB questions, for a total of two baseline *alternate* trip responses for each respondent.

Table 1. Harvester Characteristics

Variable	Mean or Percent of Sample
Days harvesting clams last year	3.7
Days harvesting oysters last year	2.4
Use private beach most often	26.7%
Use multiple beaches	34.5%
One-way travel distance to most used beach	33.75
Round-trip travel cost to most used beach	$29.86
Household income	$80,242
Age	53
Female	33.3%

not been observed, so this combination did not appear on the survey instrument. The remaining combinations form the equivalent of a 3·4 factorial design, which was blocked across survey versions to form the final design for these CB questions.

In order to estimate the demand for trips, we calculated travel costs (the price for this recreational good) for each of these trip types. We calculated travel costs to the beach each respondent reported using most often as well as to the substitute beach described in the CB questions. The costs associated with a shellfish harvesting day trip are composed of transportation costs and a measure of the opportunity cost of time.

Transportation costs are composed primarily of driving costs, but also include costs related to ferry transit, parking, and boat usage[10] for some respondents who reported these expenditures on the survey. The survey instrument elicited driving distance to the beach most often used, and most respondents provided this number. For individuals who provided the name of the beach but not the driving distance, this calculation was made using Google maps. Driving costs per mile were taken from the published operating costs[11] for a representative vehicle in 2013: $0.20 (AAA 2013). Ferry costs were taken from published fare schedules (Washington State Department of Transportation 2013) for respondents who stated that they used a ferry.

The opportunity cost of time was taken as one-third of the wage rate.[12] For the purpose of this calculation, travel times were calculated using Google maps and include any time that would be spent on a ferry.

In order to avoid allocating travel costs from multi-day or multi-purpose trips to shellfish in an ad hoc manner, we focus the analysis on the majority of respondents who take single-day harvest trips. Later research will be devoted to analyzing multi-day trips.

ESTIMATION

We estimate parameters of the model using a negative binomial (NB) functional form in order to allow the variance to be greater than the mean (overdispersion), a common feature of recreational trip data (Haab and McConnell 2002).

10. Some sites are only available by boat. Approximately 7% of respondents use a boat to reach the harvesting site they use most often.

11. Hang et al. (2016) find that household trip behavior is consistent with our definition of travel costs, which excludes depreciation.

12. While we acknowledge that there is an extensive debate regarding the measurement of opportunity cost of time and recent work has suggested a higher value may be supported (e.g., Fezzi, Bateman, and Ferrini 2014), we proceed with the more conservative, and more standard, fraction of one-third. Approximately 7% of respondents did not provide data to calculate a wage rate, and were therefore dropped from the sample during estimation.

Now, we will ask you about a few specific situations when a beach closure might affect the number of trips you typically make during a harvest season (January through December), depending on the

- **Type of Closure**,
- **Period of Closure**,
- **Species Closed to Harvest**, and the
- **Additional Distance to a Nearby Beach that is Fully Open**

C3 Suppose that the Department of Health has closed an area for the entire season (January through December) that includes the Puget Sound beach you most often use for harvesting clams or oysters and there is a nearby beach that is not affected by this closure that is an additional 20 miles away.

Please review the following table and answer the questions below.

Information on the Closure and Your Alternatives	
Type of Closure	Biotoxin
Period of Closure	January through December
Species Closed to Harvest	Butter Clams Only
Additional Distance to a Nearby Beach that is Fully Open	20 miles

C3.1 **During this 12 month closure**, how many trips would you take to the beach you most often use, and to the nearby beach that is fully open?

Trips during the closure (January through December) to the beach you most often use:

Harvesting trips: ☐☐

Non-harvesting trips: ☐☐

Trips during the closure (January through December) to the nearby beach that is fully open (20 additional miles):

Harvesting trips: ☐☐

C3.2 For comparison, suppose instead that this closure would not occur. How many harvesting trips to the nearby beach (20 additional miles) would you now take during January through December?

Harvesting trips in January through December to nearby beach if no closure: ☐☐

Figure 1. Example CB Question from the Survey

Baseline preferences for different trip types are likely to be heterogeneous across the recreational harvesting population, even among users of the same beach type (public or private). This could be due to different levels of familiarity with the beach and alternate beaches nearby, available time for recreation, or the availability of substitute activities. We allow for this by specifying each θ_i to be normally distributed across the population.[13]

Given this specification, we proceed using maximum simulated likelihood estimation with 25,000 Halton draws (Train 2009). Estimation is conducted in Nlogit (version 5).

13. We restrict the off-diagonal elements of the covariance matrix of the mixing distribution to be zero.

RESULTS

First, we note that the chosen model specification is supported empirically: the NB functional form is favored over the more restrictive Poisson as the estimated dispersion is significantly different from zero, and baseline demands for trip types exhibit significant heterogeneity, as shown by the significant standard deviations for the θ parameters.

Most of the estimated parameters in our model are statistically significant (table 2). All of the own price coefficients are negative and significant ($P < 0.01$). Demand for alternate beach trips is more elastic than demand for harvest trips to a respondent's most used beach, and demand for non-harvest trips is more elastic than either type of harvest trip. In the incomplete demand system, the sign of the income parameter determines whether the goods are substitutes or complements (equation 3 in Englin, Boxall, and Watson 1998).[14] In our application, $\gamma > 0$ and therefore trip types are seen to be substitutes. Approximately one out of every four respondents in our sample uses a private beach to harvest clams or oysters, and these respondents have lower baseline demand for trips ($\rho < 0$).

Consistent with ex ante expectations, closures of the beach most often used by a respondent are seen to significantly reduce the demand for harvest trips to that beach. However, demand does not drop to zero; some level of harvest continues under both pollution and biotoxin closures (figure 2).[15] When these closures occur, the demand for harvest trips to an alternate beach that is unaffected by the pollution or biotoxin event is increased. In contrast, harvest closures do not seem to have any impact on the demand for non-harvest trips. Across all three trip types, the net effect of a harvest closure is a reduction in the number of total trips that would be taken (figure 2); increased trips to an alternate beach do not fully offset the decreased trips to the beach used most often.

We do not find much evidence of a differential impact across closure types on the demand for trips. Stated behavior does not significantly depend on whether the beach is closed for pollution or biotoxins or whether the closure is for all species or restricted to butter clams only.

Estimates of annual demand, by trip type, illustrate some of these results (figure 2). For these calculations, we use a baseline scenario of no closures with the nearest substitute beach an additional 20 miles away.[16] The average number of harvest trips to the most used beach, harvest trips to an alternate beach, and non-harvest trips to the most used beach demanded are 4.50, 0.40, and 0.12, respectively.[17] When the most used beach is closed to harvest due to pollution, the average number of harvest trips to the most used beach, harvest trips to an alternate beach, and non-harvest trips to the most used beach demanded are 0.69, 1.21, and 0.12, respectively. This represents a decline of 85% in harvest trips to the closed beach and a decline of 60% in total trips.

14. Recall that compensated cross-price effects in the model are equal to the products of the income parameter and the quantities of trips to the sites in the system: $\gamma x_i x_k$ for trip type i and k.

15. In the context of a closure for butter clams only, other species of clams and oysters remain safe for consumption, so it may not be surprising to see some level of harvesting effort for other species remains. Harvesting during a closure for *all* species may be more surprising. However, this result is in line with the survey pre-testing and an analysis conducted by Washington Department of Fish and Wildlife (Strom, Weiss, and Bradbury 2009); some harvesters simply do not alter their behavior for these closures.

16. Note that a baseline of no biotoxin or pollution closures may not mirror the baseline conditions at certain beaches in Puget Sound, where these harvest closures are somewhat common.

17. These calculations were performed at the sample averages.

Table 2. Parameter Estimates from Mixed Negative Binomial Model

Variable			Coefficient Mean (standard error)	Coefficient SD (standard error)
Trip types (θ_i)	Harvest		1.69819***	0.77735***
			(0.10298)	(0.05708)
	Alternate		–0.56257***	1.38093***
			(0.11119)	(0.06435)
	Non-harvest		–1.84539***	2.89039***
			(0.22509)	(0.13437)
Price (β_i)	Harvest		–0.00783***	
			(0.00184)	
	Alternate		–0.0081***	
			(0.00152)	
	Non-harvest		–0.01053***	
			(0.00245)	
Closed (δ_{ni})	Harvest	Biotoxin, all species	–1.69773***	
			(0.13214)	
		Biotoxin, butter clams	–1.50156***	
			(0.12557)	
		Pollution	–1.87221***	
			(0.15284)	
	Alternate	Biotoxin, all species	0.99405***	
			(0.15097)	
		Biotoxin, butter clams	1.25347***	
			(0.15112)	
		Pollution	1.10273***	
			(0.18102)	
	Non-harvest	Biotoxin, all species	0.02859	
			(0.23116)	
		Biotoxin, butter clams	0.07575	
			(0.27536)	
		Pollution	–0.0073	
			(0.25834)	
Income (γ)			.11731D–05*	
			(.6650D–06)	
Priv (ρ)			–0.20512***	
			(0.07342)	
NB Dispersion			2.15745***	
			(0.17215)	
Respondents	165			
Sample size	1,650			
Log-likelihood at zero	–9,998.326			
Log-likelihood at convergence	–2,282.449			

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

WELFARE ESTIMATES

The parameter estimates from our model are used to construct measures of WTP. Specifically, we calculate WTP for the baseline (harvest access with no pollution or biotoxin closures), as well as WTP under annual closures of different types and spatial extent. We present WTP on an annual basis and on a per-trip basis.

Though we calculate both Marshallian and Hicksian measures of WTP, we find the differences to be quite small due to a negligible income effect and limit the presentation of the results

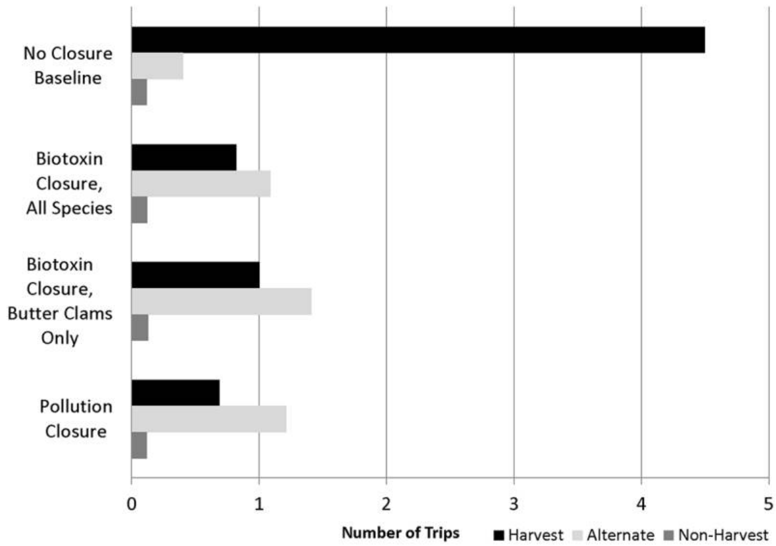

Figure 2. Estimated Number of Trips by Closure Type

to compensating variation (CV) in what follows. Hicksian WTP (in this context, CV) for trip type i is calculated as $(-1/\gamma)ln(1 + (x_i\gamma/\beta_i))$ (Englin, Holmes, and Niell 2006). The average WTP for a shellfish harvesting day trip to the beach used most often by a respondent is estimated to be \$127.66.[18] Not surprisingly, the estimate of average WTP for a non-harvesting day trip is lower: \$94.93. In order to test whether differences in WTP for trip types are statistically significant, we first use the bootstrapping procedure of Krinsky and Robb (1986) to generate random distributions of WTP[19] and then calculate p-values as the proportion of resulting values that are negative (Poe, Welsh, and Champ 1997).[20] Results indicate that the differences in WTP across trip type are not significant at usual standards of significance.[21]

The effect of an annual closure consists of two components in our model: a fixed effect and a portion that varies with distance to the nearest beach open for harvest. This dependency on a substitute's proximity adds a dimension to our estimate of WTP that cannot be illustrated with a single point estimate. We therefore present annual WTP over the three trip types in the demand system conditional on distance to the nearest substitute beach open for harvest, focusing on the four levels of the distance attribute contained in our experimental design (table 3). Note that these WTP calculations are aggregate values over the three trip types in the demand system. These results illustrate that harvest closures have a relatively large overall impact on WTP, even when a close substitute site remains open for harvest. As an example, if a substitute beach is 20 additional miles away, the average shellfish harvester is willing to pay \$635.49 per year when there are no biotoxin or pollution closures at the beach they use most often. Annual WTP falls

18. For comparison, consumer surplus for a shellfish harvesting day trip is estimated to be \$127.65 $(-1/\beta_i)$.

19. We use 10,000 simulations here.

20. Note that overlap in confidence intervals is not sufficient to determine whether two estimated means are statistically different from one another (Poe, Severance-Lossin, and Welsh 1994).

21. P-values for the tests of differences between *harvest* and *non-harvest*, *harvest* and *alternate*, and *non-harvest* and *alternate* are 0.185, 0.449, and 0.199, respectively.

Table 3. Annual Mean WTP by Closure Type and Distance to Nearest Open Beach and 90% Confidence Intervals

	Additional Miles to Open Beach			
Closure Type	5	10	20	30
No closure	$641.14	$639.19	$635.49	$632.05
	($467.66, $1,036.73)	($465.77, $1,034.92)	($462.48, $1,031.31)	($458.97, $1,027.86)
Biotoxin, all species	$266.52	$261.25	$251.26	$241.96
	($208.23, $389.50)	($203.49, $383.25)	($194.68, $371.53)	($186.48, $360.71)
Biotoxin, butter clams only	$334.21	$327.38	$314.43	$302.37
	($262.61, $479.85)	($256.58, $472.19)	($245.06, $457.47)	($234.45, $443.59)
Pollution	$266.46	$260.59	$249.45	$239.08
	($209.47, $383.55)	($204.44, $376.78)	($194.49, $363.80)	($185.61, $351.93)

to $249.45 if this beach is closed for the year due to pollution. Equivalently, the average shellfish harvester would be willing to pay $386.05 per year to avoid a year-long pollution closure on the beach they use most often when the nearest open beach is 20 additional miles away. Similar values are found in table 3 for biotoxin closures, along with Krinsky-Robb 90% confidence intervals of mean WTP (Krinsky and Robb 1986).[22]

Next, we decompose the effect of a closure into its fixed and variable (with respect to distance to nearest open beach) components. The fixed component can be seen by comparing WTP under no closure to WTP under a harvest closure, and the variable component can be seen by comparing WTP values under harvest closures of varying geographical extent. Based on our estimates, the fixed component of a closure vastly exceeds the variable component; increasing the number of miles a shellfish harvester must travel in order to reach the nearest open beach has relatively little effect on WTP (figure 3). These results suggest that individual harvest beaches have significant value, as the availability of nearby substitutes does not greatly temper the economic losses associated with a closure. This result may be driven by the familiarity with a given beach and associated harvesting knowledge or, equivalently, the unfamiliarity with alternate nearby beaches. Another explanation could be related to precautionary behavior; a full-year health closure as close as five miles away from a harvesting beach may discourage some of the potential substitution that might otherwise occur.

To provide additional context, we compare the values we find here to existing WTP estimates for similar trip types.[23] In addition to the limited studies of shellfish harvesting, we turn to the literature on recreational beach demand and recreational fishing for finfish. For the purposes of these comparisons, we first translate all estimates to 2013 USD, using the CPI and foreign exchange rates, where necessary.

Relative to our daily WTP estimate of $128, Whitehead et al. (2008) estimate a value of $114 for recreational beachgoers in North Carolina, Penn et al. (2016) find values of $57 for an ideal day at the beach and $16 when calculated at average levels of their experimental design for Hawaiian residents, Parsons et al. (2009) estimate losses that range from $3 to $73 per trip for closures of sets of beaches in Texas, and Beaumais and Appéré (2010) provide point estimates of $198 and $487 per day, depending on the model chosen, for recreational shellfish harvesting in

22. These confidence intervals are formed using 10,000 simulations.

23. To be clear, the purpose of our comparison is not to suggest that benefits should be transferred casually from studies of alternate contexts (Plummer 2009).

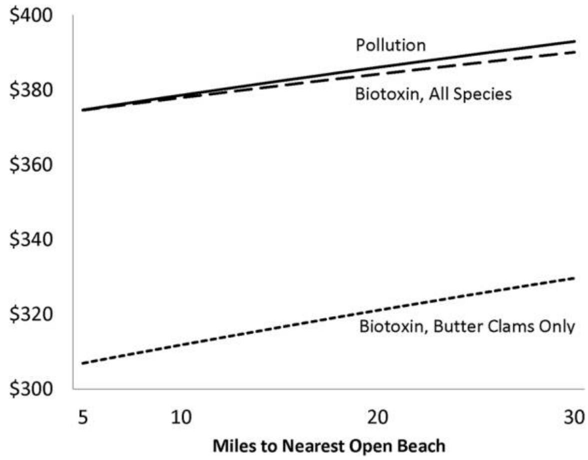

Figure 3. WTP to Avoid Harvest Closure, by Mileage, to Nearest Open Beach and Closure Type

France. In a recent meta-analysis, Moeltner and Rosenberger (2014) include two region-activity pairs closely related to our context: west saltwater fishing and west beach. Mean estimates of WTP for these activities are $164 (with a range of $7–$431) and $17 (with a range of $2–$97), respectively.

Relative to our annual WTP estimate of $386 to avoid a pollution closure when the closest open beach is an additional 20 miles away, Phaneuf, Kling, and Herriges (2000) find that anglers are willing to pay $198 per year for a 20% reduction in toxics in the Great Lakes; Awondo, Egan, and Dwyer (2011) estimate the value of improved water quality to beachgoers on Lake Erie from the construction of a wetland is in the range of $186 to $213; and Beaumais and Appéré (2010) find that shellfish harvesters in France are willing to pay $126 or $311 per year, depending on the model chosen, in order to avoid a downgrade in sanitary water quality.

In general, there is some agreement between our estimates of WTP and those in the literature. Though our values are higher than some, they are certainly within the range of existing published studies. It is also apparent that existing estimates vary widely, likely influenced by both contextual and methodological differences between the studies. One factor that may be unique to shellfishing is the relatively small window of opportunity. Harvesting is essentially limited to very low tides that occur during daylight hours. When closures of all types (harvest, pollution, biotoxin) are overlaid on top of these already-limited opportunities, there are few chances for harvest relative to, for example, recreational fishing or non-harvest beach trips.

Finally, we note that there is a possibility of bias in all stated preference research.[24] If harvesters provide trip estimates for the CB scenarios that do not fully reflect other constraints on their time, for example, the WTP estimates we provide here would be artificially inflated. We have attempted to minimize this possibility by conducting extensive survey pre-testing, including close substitutes directly in the analysis, and eliciting baseline demands under the same framework as the beach closure scenarios, but without the collection of additional revealed preference

24. For a discussion in a CB context, see Whitehead et al. (2008).

data to test for convergent validity, we cannot be certain that intended demand would correspond with actual demand.

CONCLUSION

This study examines the effect of annual biotoxin and pollution closures on the demand for recreational clam and oyster harvesting day trips in Puget Sound, Washington. An incomplete demand system is used to model harvest trips to the beach most often used by each respondent, non-harvest trips to the same beach, and harvest trips to a nearby substitute beach.

We estimate annual WTP under a baseline of no closures and describe how WTP changes under both biotoxin and pollution closures. We show that there is a significant loss in value associated with any type of harvest closure. While some level of harvest would continue at closed beaches and some of the harvest effort would shift to nearby beaches that remain open for harvest, our model estimates a sizeable net reduction in overall trips. We find very little difference between the effect of a pollution closure and the effect of a biotoxin closure. The WTP results we provide here should be useful to shellfish managers tasked with allocating the harvest or directing resources to prioritize monitoring and restoration activities. For example, a number of beaches in the Sound have been closed to harvest for multiple years due to pollution. While beyond the scope of this article, the model could be used to estimate the benefit to recreational clam and oyster harvesters associated with opening these beaches, or from preventing future closures, and compare these benefits to the estimated costs of such a restoration. Similarly, WTP estimates could be used to measure damages caused to recreational shellfish harvesters from a pollution event that closes a section of the Sound, such as an oil spill or a localized issue with septic systems in a community.

There seems to be relatively few applications in which researchers have collected stated behavior data at the seasonal or annual level (as opposed to the choice occasion level) using an experimental design. Here we demonstrate that this approach can be successfully used to estimate recreational demand models that are well suited to produce measures of seasonal or annual WTP, such as an incomplete demand system.

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